AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
STRUCTURAL ENGINEERING DEPARTMENT

Pile group action under vertical loads in different soil types

Thesis
Submitted in Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE
In
CIVIL ENGINEERING
STRUCTURAL ENGINEERING DEPARTMENT
By

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Cairo – 2019

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College Board approval / / 2019

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STATEMENT

This thesis is submitted to Ain Shams University for the degree of M.Sc. in Civil Engineering.

The work included in this thesis was carried out by the author at the Department of Structural Engineering, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

No part of this thesis has been submitted for a degree or a qualification at any other University or Institution.

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ACKNOWLEDGMENT

First and foremost thanks to GOD for his many graces and blessings.

I wish to express my deepest gratitude and appreciation to Prof. Dr. Yasser Moghazy El-Mossallamy, Professor of Geotechnical engineering, Structural Department, Faculty of Engineering, Ain Shams University for his kind supervision, patience, help, guidance, fruitful comments, and valuable advice.

My grateful appreciation also extends to Dr. Sayed M. Ahmed El-Araby, Associate Professor of Geotechnical engineering, Structural Department, Faculty of Engineering, Ain Shams University for his patience, help, guidance, useful suggestions, dedication and encouragement throughout this research till its completion which is gratefully acknowledged and sincerely appreciated.

Most importantly, my deepest thanks and love for my family. Your constant and everlasting support is the reason I was able to finish this research.

ABSTRACT

Using piles as foundation elements had escalated as the number of high-rise buildings as well as heavy structure (e.g. LNG tanks, silos, and bridges) had increased through the past years. The main purpose of piles is to transmit the loads from the shallow weak layers to deeper and stronger layers of soil to provide the required bearing capacity or control the structural settlement. As in most cases, the pile foundations consist of a group of piles beneath the pile cap or the building raft, hence studying the behavior of the group of piles compared to that of a single pile has been a scope of work for many researchers. The pile group ultimate capacity and the settlement of the group of piles is affected by many factors such as the pattern of piles, the pile's diameter, the pile's length, the spacing between piles and the surrounding soil type and state. The behavior of the group of piles is completely different from that of a single pile. In this thesis, the behavior of the group of piles under vertical compression as well as tension loads in different soil types is studied using advanced three-dimensional finite element analyses and compared with the behavior of the single pile.

Two types of pile group action shall be taken into consideration, the first one deals with the ultimate capacity of the pile group (pile group efficiency). The second one deals with the settlement of the pile group under working load (pile group action). The group behavior in both cases is compared with the single pile behavior.

Well-documented cases of history were verified using advanced three-dimensional finite element analyses to examine the validity and accuracy of the proposed different soil parameters in determining the pile group settlement and

the group ultimate capacity and consequently, the pile group behavior compared to the single pile behavior. Then the same soil types and states of the verified cases of history were adopted using the hardening soil constitutive law with the same parameters and a parametric study had been performed on groups of piles to evaluate the effect of changing number of piles, pile length and spacing between piles on the behavior of the group of piles for both terms of pile group action and pile group efficiency.

Key Words: Group of piles, pile group action, pile group efficiency, settlement of group of piles, overconsolidated clay.

SUMMARY

Rafts on piles are considered one of the most effective techniques used either when heavy loads of high-rise buildings are to be transmitted to the deeper soil deposits to fulfill the bearing capacity limits or to control the settlement of these heavy buildings by transmitting the loads into more stiff layers of soil. Hence, so many studies have been performed to help us understand the behavior of the group of piles under reinforced concrete rafts.

The main objective of this research is to investigate the behavior of the group of piles under reinforced concrete rafts in different soil types and the interaction between the group of piles and the surrounding soil clusters and comparing that behavior with the single pile behavior in both terms of pile group action and pile group efficiency.

The research presents a numerical study using a finite element analysis method using three-dimensional modeling of the problem of the behavior of the group of piles in overconsolidated clayey soil. A case study reported at Alzey, Germany (1974) of a highway bridge rested on two pile caps each rested above 6 piles is undertaken and modeled in three-dimensional models with different constitutive laws and the results of the performed models are compared to the actual readings measured at the field during and after construction.

Finally, a parametric study is performed to study the effect of different factors affecting the behavior of the group of piles compared to the behavior of the single pile in both sides of bearing capacity and vertical deformation in overconsolidated clayey soil and very dense sand.

The thesis consists of these six chapters:

Chapter (1) is the introduction to this research; it discusses the importance, the scope and the main objectives of the research.

Chapter (2) is a literature review which briefly discusses through the past researches the behavior of the group of piles in the different soil in terms of pile group action (settlement of group of piles in comparison with it for the single pile) and also the pile group efficiency (the ultimate bearing load for group of piles divided by the number of piles compared to the load of a single pile).

Chapter (3) presents a brief discussion about the finite element method including analysis sequence and different types of elements that may be used in the analysis. Also, different constitutive laws in geomechanics are highlighted. In addition, the utilized material models are provided. Finally, the finite element analysis program PLAXIS which is used during this research is briefly discussed.

Chapter (4) in this chapter a discussion of a case study description including the actual location, soil profile, soil parameters, number of piles, pattern of piles, and the applied loads. In addition, the monitored deformation values during the construction and the operation of the bridge are introduced. A set of three-dimensional numerical models were established to investigate the behavior of the group of piles in the defined soil and the resulted deformation and pile loads. Finally, the comparison between the monitored results and the numerically predicted response of the three-dimensional model is presented at the end of this chapter to confirm the ability of the numerical modeling three-dimensional program to simulate the reality with close results.

Chapter (5) a parametric study is presented with its results in this chapter as it was conducted to investigate the effect of different parameters on the load carrying capacity of the stone column. The effect of piles spacing, piles length, and type of soil on the pile group behavior in terms of ultimate load and settlement.

Chapter (6) the summary and the conclusions of this research are presented ended up with the suggestions for future studies and research topics relevant to the subject.

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